Introduction

The Lower Murray Floodplain is generally a saline environment, both in the groundwater and in the unsaturated zone. While native vegetation species are salt-tolerant, it is essential that sufficient, soil moisture of appropriate salinity is available to sustain growth and life cycle processes. Surface inundation is commonly employed to replenish soil moisture with appropriate salinity water.

The intent of this paper is to raise awareness that low salinity groundwater lenses provide an important, ephemeral to permanent alternate source of water to the unsaturated zone, to support the ecological function of floodplains in an otherwise dry and saline environment.

Groundwater 101 for Ecologists

The response of large floodplain flora to management actions is largely determined by the amount of low salinity water that is made available to vegetation in the unsaturated zone, and the length of time it remains available. The following definitions reflect the key terms that are used in describing groundwater in relation to vegetation management.

- The unsaturated zone is the interval between the ground surface and the water table, where soil moisture and air occur in pore spaces of the geologic materials, at varying proportions.
- The water table defines the elevation below which the pore spaces are completely filled with water.
- The water table may occur within an aquifer (geologic materials from which useful volumes of water can be extracted via a bore or well e.g. sands and gravels, limestone, fractured rock) or an aquitard (geologic materials that retard the flow of water e.g. silts and clays, unfractured rock).
- The capillary rise from the water table is small in sands and gravels (10's of centimetres) and large in clays (many metres).
- Evaporation extracts water from the soil surface and evapotranspiration draws water from the subsurface via the agency of plant roots. Both processes extract water and leave salt behind in the soil profile. Evaporation is only modestly affected by the salinity of the soil moisture, evapotranspiration is significantly affected by the salinity of the soil moisture.
- Low salinity lenses occur in saline groundwater systems and form a distinct layer of low salinity groundwater over more saline groundwater (Figure 1). The low salinity lenses are maintained by the density contrast between low salinity and saline groundwaters, and usually exhibit very sharp boundaries in saline environments.

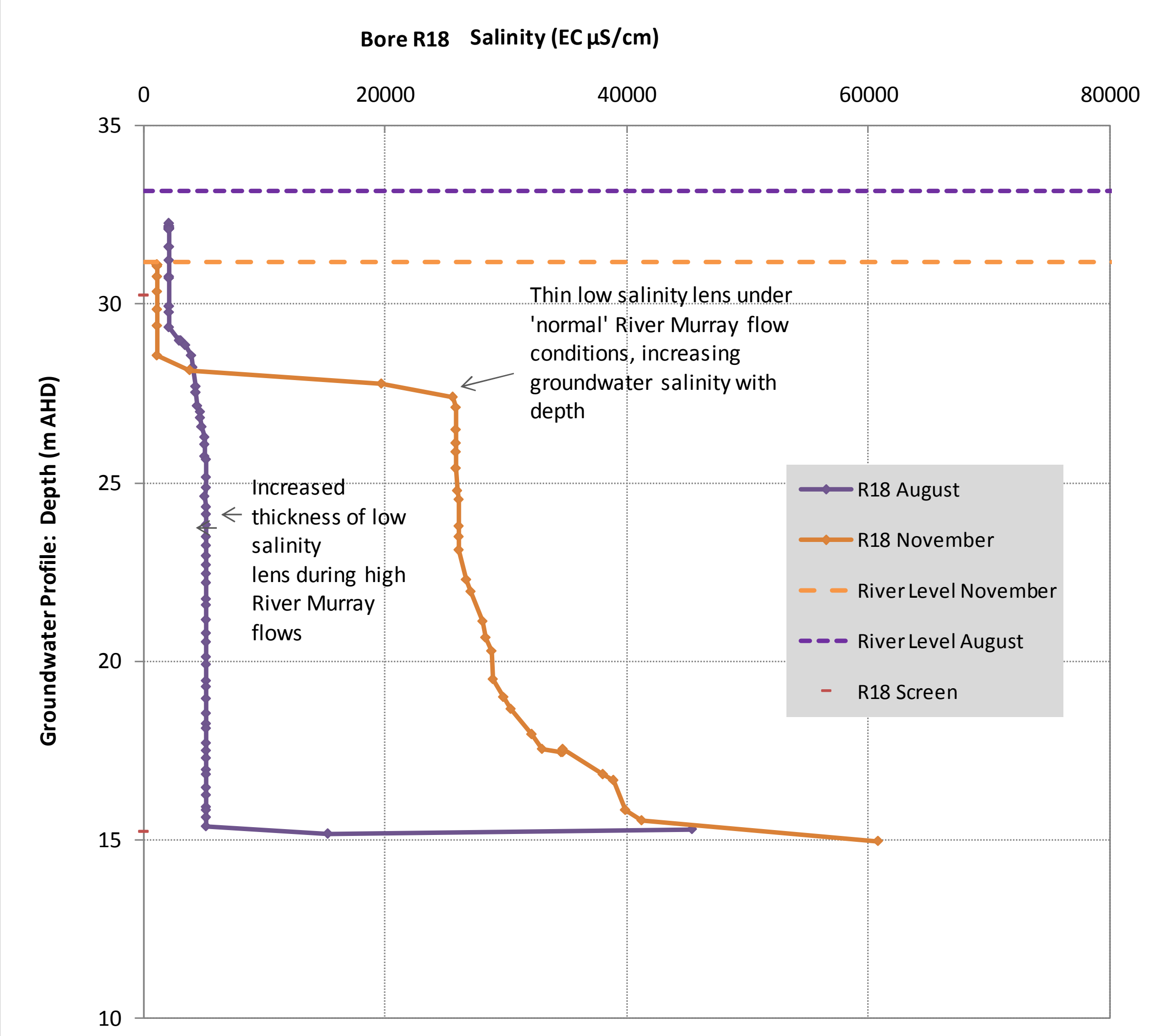

Figure 1: Groundwater salinity profiles showing changes in low salinity lens thickness in response to river flows

Salinity Thresholds and Moisture Availability

A range of studies have assessed the salinity tolerances of River Red Gum and Black Box trees. River Red Gum trees can tolerate semi-saline groundwater conditions and have an upper tolerance limit of ~30,000 μ S/cm (19,500mg/L) (Overton & Jolly, 2004). Prolonged exposure to groundwater of this salinity will have significant impacts on growth, especially when coupled with other stresses such as drought (MDBC 2003; Overton & Jolly, 2004). Black Box trees show an upper tolerance limit of ~55,000 μ S/cm (~35,750mg/L) (Sharley & Huggan, 1995; Overton & Jolly, 2004, AWE 2012).

Black Box displays a greater salt tolerance than River Red Gum but has a lower tolerance for flood inundation. Although Black Box trees can survive at relatively high salinities, vegetation vigour can begin to decrease at moderate groundwater salinities, especially where the water table is shallow, within 2 to 4 m of the surface. Roberts & Marston (2011) suggest a flooding frequency of 1 in 5-10 years for healthy growth, based on the natural flood frequency associated with tree distribution on the floodplain. However, the flood frequency required to maintain healthy growth will be influenced not only by the flood frequency, but also by the salinity of the underlying groundwater. Periodic access to low salinity groundwater or surface water is essential.

Low salinity soil moisture in the unsaturated zone can be sourced from:

- Vertical downward recharge by infiltration of rainfall.
- Vertical downward recharge by inundation of the floodplain by overbank flows.
- Lateral recharge from surface water bodies (River or lakes) where losing stream conditions exist or through bank recharge during floods (low salinity lenses).
- Capillary rise from groundwater, where the soil texture will influence the height of the capillary fringe and will be higher in clays than in sands.

Floodplain Vegetation Management Strategies

The response of large floodplain flora to management actions is largely determined by the amount of low salinity water that is made available to vegetation and the length of time it remains available. The Floodplain Response Conceptual Model (Figure 2), illustrates the key relationships between water management (i.e. groundwater and surface water management), soil salinity and groundwater salinity and tree health response.

Previous studies have identified riparian vegetation condition can be improved by the creation of a long-term source of low salinity soil moisture (i.e. a low salinity groundwater lens) (e.g. Doody et al. 2009, Holland et al. 2009 and Holland et al. 2011). Surface water manipulation strategies (e.g. flooding) have the potential to increase the availability of low salinity soil moisture in the unsaturated zone and perhaps influence the salinity of the saturated zone (i.e. the groundwater). Groundwater manipulation has been shown to introduce low salinity water into the aquifer, and from there influences the salinity of the overlying unsaturated zone.

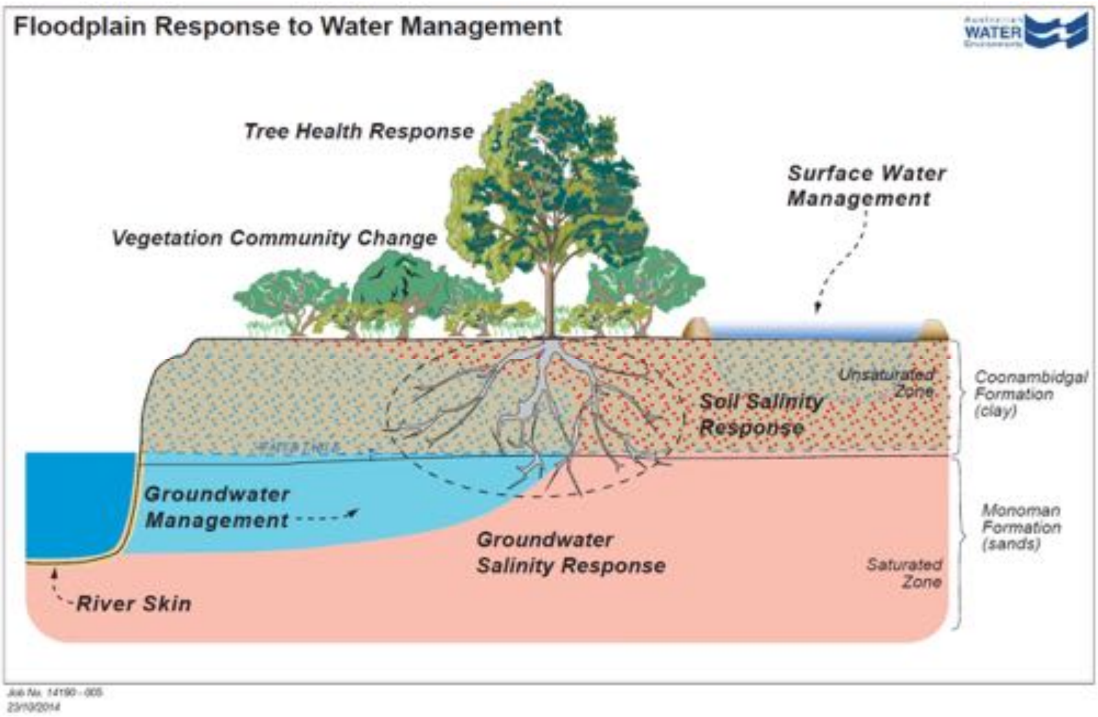

Figure 2: Floodplain Response Conceptual Model (AWE 2016b)

A range of management strategies have been employed along the Lower River Murray floodplain that aim to improve vegetation condition, these include:

- Inundation of ephemeral wetlands to increase soil moisture availability, reduce soil salinity and potentially freshen groundwater via vertical infiltration through the wetland bed or via lateral recharge through the bank.

- Inundation of low lying floodplain areas to mimic overbank flows from large floods with the aim of increasing soil moisture availability, reducing soil salinity and potentially reducing groundwater salinity via vertical infiltration of water through floodplain soils.
- Irrigation of floodplains using dripper or sprinkler irrigation to increase soil moisture, reduce soil salinity and potentially reduce groundwater salinity via vertical infiltration of water through floodplain soils.
- Pumping groundwater to generate or enhance freshwater lenses with the aim of providing a freshwater source for trees and potentially reducing soil salinities through interaction with the watertable.
- Injection of water into the floodplain aquifer to provide a freshwater source for mature trees and potentially reduce the salinity of the unsaturated zone through interaction with the water table.

Managing Groundwater

The most common approach for floodplain management is environmental watering by surface inundation, where low salinity water is introduced to the unsaturated zone via vertical infiltration. Surface watering is particularly important for triggering seed germination and supporting recruitment. However, the recharge flux from inundation is limited by the vertical conductivity of floodplain soils, which are commonly clayey along the Lower Murray Floodplain. Recharge rates are typically only 1mm/day on the higher terraces, and perhaps 10mm/day on the lower, sandy terraces.

As an alternative there are an increasing number of examples where floodplain management directly targets groundwater. These strategies directly manipulate groundwater to create or enhance low salinity lenses, to induce changes in the unsaturated zone and hence the salinity of soil moisture available to large floodplain flora.

Clark's floodplain at Bookpurnong, on the River Murray in South Australia, is one of the most intensely studied sites in terms of floodplain management from a groundwater perspective. The site has a long history of and significant investment in, projects that aim to manage salinity and improve floodplain vegetation condition. These projects have involved a wide range of stakeholders including government departments, private landholders and irrigators, community groups and research institutions with outcomes from the trials documented by a series of authors, including but not limited to; AWE 2016a, AWE 2005, Berens et al. 2009, Doody et al 2009, Hamilton-Smith 2013, Holland et al 2013 and Holland et al. 2011.

A key experimental objective of the trials at Bookpurnong (AWE, 2005) was to quantify if a low salinity lens would be formed by pumping groundwater from the floodplain aquifer, and to quantify changes in the unsaturated zone salinity and vegetation health in response to the formation of a lens. The experiment was successful, and a low salinity lens was created on Clark's Floodplain between the River Murray and the Living Murray Bore (LMB) as a result of groundwater pumping at the site since 2005. Monitoring data sets from the trial that map the progression of the lens in response to groundwater pumping are shown in Figure 3 and Figure 4. Additionally, Doody et al. (2009) identified improvements in floodplain vegetation condition within 6 months of the creation of the low salinity lens. The Living Murray Bore continues to operate today, maintaining the low salinity lens as a water source for vegetation at Clark's Floodplain.

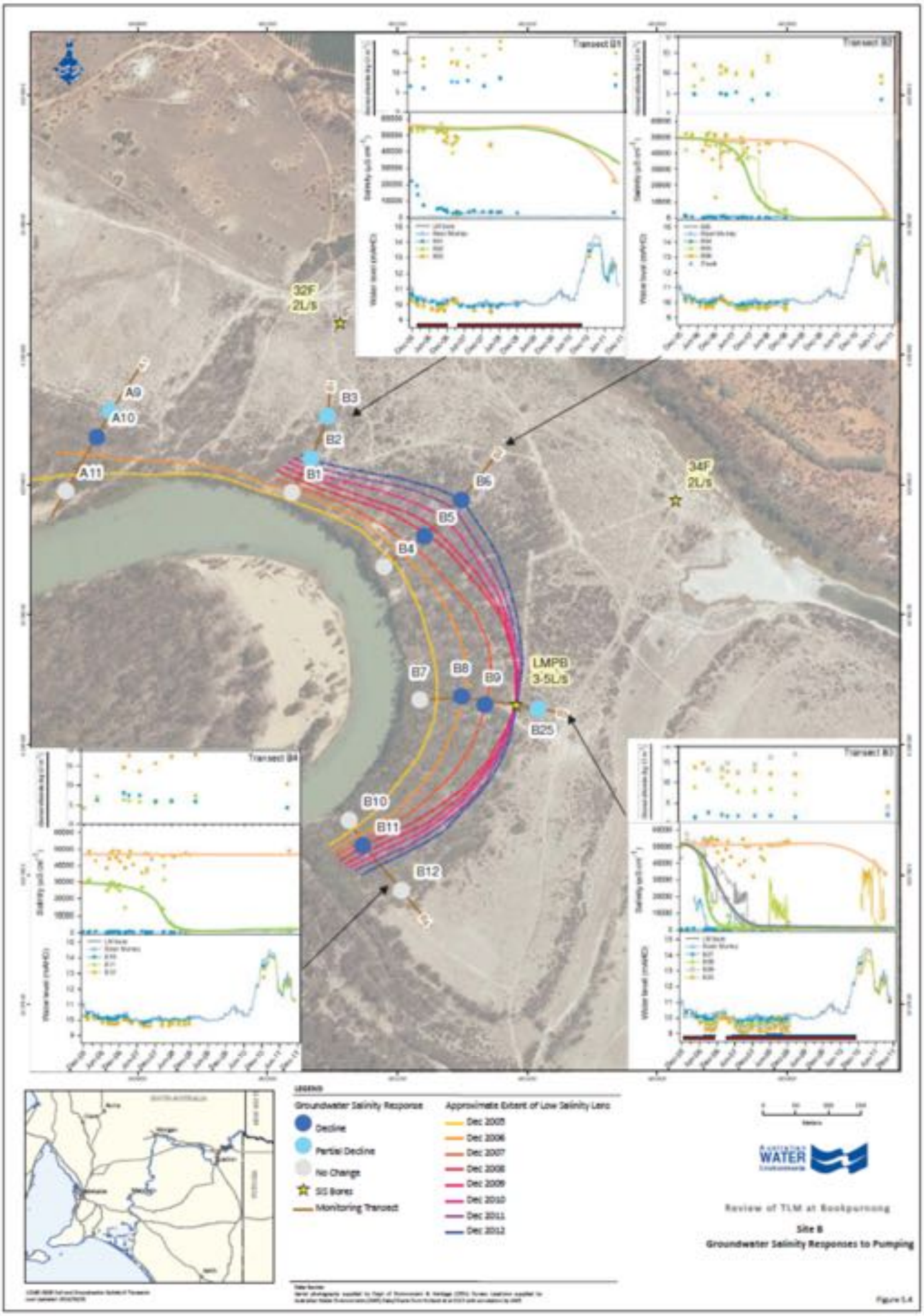

Figure 3: Low salinity lens development from groundwater pumping (Holland et al 2013 and AWE 2016a)

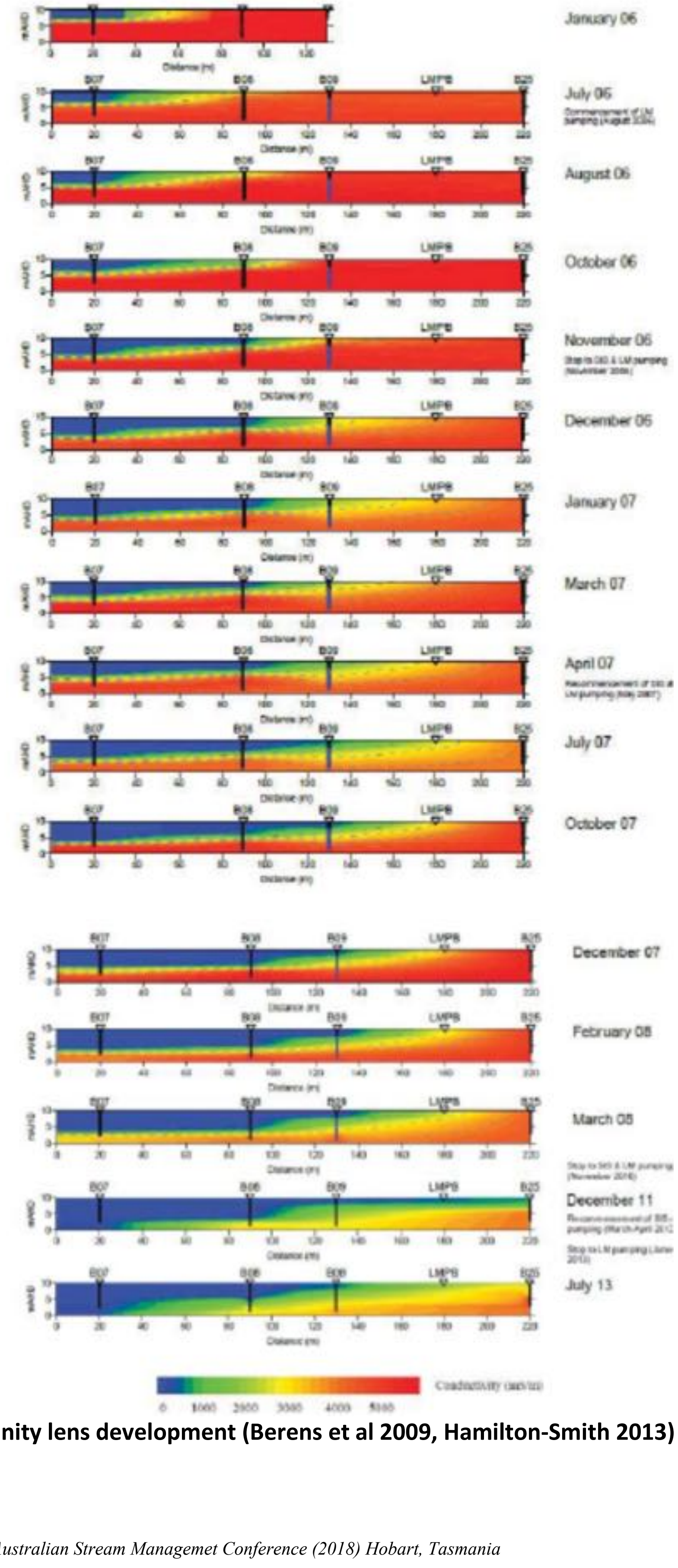

Figure 4: Low salinity lens development (Berens et al 2009, Hamilton-Smith 2013)

Project Example: South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP)

SARFIIP aims to develop floodplain infrastructure that will address the continuing decline in ecosystem health and deliver improved ecological outcomes for floodplains along the Lower River Murray in South Australia, with particular focus on the Pike and Katarapko Floodplains. SARFIIP is funded by the Australian Government through the Murray–Darling Basin Authority and implemented by the Department for Environment and Water in partnership with SA Water.

The major focus of the proposed management actions for the Pike and Katarapko floodplains is the construction of regulators and banks to facilitate floodplain inundation at low flows and to offset the reductions in natural flood frequency (Inundation Measures). It is an innovative project, seeking to increase the availability of low salinity water to improve ecosystem functions in a predominantly saline system. The SARFIIP program therefore also includes Salinity Management Measures to develop and construct groundwater infrastructure that manages the risks and enhances the benefits of inundation.

Water Technology has been engaged as the design contractor to develop groundwater management infrastructure for SARFIIP. The practice of managing long-term salinity risks is well established through the Salt Interception Scheme program, but the management of ecological risk and the enhancement of ecological benefit from a groundwater perspective is a relatively new concept, and SARFIIP is the first instance where it has been actively considered in groundwater management along the River Murray.

The primary outcome of the concept design phase of the project has been the construction of a groundwater management scheme (borefield). The scheme has been designed through various field programs including investigation drilling, bore construction, aquifer testing and groundwater monitoring. A numerical groundwater model was also developed as a design tool to inform the design of the borefield and pipeline. The groundwater management scheme aims to contribute to improved floodplain ecology by:

- Increasing the extent of losing stream conditions thereby creating or enhancing the extent of low salinity lenses;
- Reducing the regional flux of saline groundwater to the floodplain;
- Reducing rates of evaporation from the soil surface by lowering groundwater levels on the floodplain; and
- Managing in-stream salinity.

The next phase of the project will focus on the design of additional groundwater management infrastructure for the Pike floodplain and consideration of a freshwater injection trial, to demonstrate the feasibility of this approach for floodplain management.

Conclusion

The close relationship between groundwater and vegetation condition needs to be understood to make best use of environmental water. There has been considerable investment in improving vegetation along the River Murray floodplain and groundwater management may provide one of the most cost-effective interventions, especially where there is existing infrastructure.

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